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from the general and publication funds shall be referred to or proposed by this Committee.

3. *The Rumford Committee, of seven Fellows, to be chosen by ballot; who shall consider and report on all applications and claims for the Rumford Premium; also on all appropriations from the income of the Rumford Fund, and generally see to the due and proper execution of this trust.*

Chapter VI., Section 4. *All moneys which there shall not be present occasion to expend shall be invested by the Treasurer, under the direction of the Finance Committe, on such securities as the Academy shall direct.*

Chapter VII., Additional Section: —

1ª. *To all books in the library procured from the income of the Rumford Fund, the Librarian shall cause a stamp or label to be affixed, expressing the fact that they were so procured.*

The following additional Standing Vote was enacted: —

2ª. *Books, publications, or apparatus shall be procured from the income of the Rumford Fund only on the certificate of the Rumford Committee, that they, in their opinion, will best facilitate and encourage the making of discoveries and improvements which may merit the Rumford Premium.*

Also voted, That the Statutes and Standing Votes as now amended be printed under the direction of the Committee on Publication.

Five hundred and fifteenth Meeting.

December 10, 1862. — MONTHLY MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read letters from Messrs. Bartlett, Searle, and A. Agassiz, in acknowledgment of their election as Fellows.

Dr. Hill read a paper "On a Geometrical Illustration of several Algebraical Theorems concerning the Roots and Powers of Monomials."

Professor Peirce showed that some modifications of the geometrical figure would render it capable of illustrating a still wider range of algebraical theorems.

Professor Hitchcock read the following paper, which was illustrated by specimens, casts, and drawings of the footprints described.

Supplement to the Ichnology of New England. By EDWARD HITCHCOCK.

Professor Hitchcock stated that this paper was the result of the examinations he had made in preparing a descriptive catalogue of the large collection of fossil footmarks in Amherst College. He had thus become satisfied that some of the species of footmarks described in his Ichnology of New England, published by the government of Massachusetts in 1858, should be given up, that some others were doubtful, but that a still large number of new ones must be added to the list. The paper also contains important additions to the Ichnology in respect to insect tracks, and points out a supposed error, as to some of the larger tracks, into which the author and others have fallen, whose correction may essentially modify our views as to the nature of the animals.

1. *Species of the Ichnology not reliable.*

BRONTOZOUM ISODACTYLUM.
PLATYPTERNA GRACILLIMA.
BATRACHOIDES ANTIQUIOR.
PTILICHNUS TYPOGRAPHUS.
PTILICHNUS PECTINATUS.
GRAMMEPUS UNIORDINATUS.

2. *Species of doubtful Character.*

AMBLYONYX GIGANTEUS.
AMBLYONYX LYELLIANUS.
ARGOZOUM REDFIELDIANUM.
PLATYPTERNA DEANIANA.
TRIDENTIPES UNCUS.

3. *New Species.*

1. ANOMŒPUS INTERMEDIUS.
2. ANOMŒPUS MINIMUS.

This genus in the Ichnology is classed among the *Marsupialoids*, but called also *Ornithoid*, combining as it does characters found now in the Marsupials and Birds. Two species are described in the Ichnology, — *A. major* and *A. minor*. Two others are now added.

3. ANISOPUS GRACILIOR. The Anisopus is also regarded in the Ichnology as *Marsupialoid;* but also *Loricoid.*

4. BRONTOZOUM ISODACTYLUM. The *B. isodactylum* of the Ichnology is probably identical with *Anomœpus intermedius,* and therefore stricken out. The present is substituted, — a much larger species.

5. GRALLATOR PARALLELUS. Having the form of *Grallator cursorius,* but much larger, yet with even a smaller stride.

6. HARPEDACTYLUS CRASSUS. } Beautiful species, which I can
7. HARPEDACTYLUS GRACILIOR. } hardly doubt belong to this genus.

8. TRIHAMUS ELEGANS. I make of this a new genus (*Trias* and *Hamus, three hooks*) as well as species, because I cannot refer the very distinct specimen which contains it to any genus of the Ichnology. It seems to have been a biped, so far as we yet know.

9. EXOCAMPE MINIMUS. Differs from the *E. ornata* of the Ichnology chiefly by its minuteness.

10. APATICHNUS CURVATUS (No. $\frac{44}{2}$ of the Cabinet). A fine track, doubtless undescribed; but I am not sure it is an *Apatichnus,* for as yet we find no fore-foot.

11. GRAMMICHNUS ALPHA. The Ichnology has two species of *Grammepus,* which means that the *foot* has the form of letters: *Grammichnus* implies that the *track* has that form. This is the true idea; and I should prefer if *Grammepus* were stricken out. Yet the *Grammichnus Alpha* is totally unlike the *Grammepus* of the Ichnology. It has the appearance of a repetition of the capital A impressed crosswise upon the trackway. But I cannot imagine even by what class of animals it was made.

12. AMPELICHNUS SULCATUS. This is the same as the *Grammepus uniordinatus* of the Ichnology. But a more careful examination shows it to be totally unlike the *Grammepus erismatus.* It is named from a not very close resemblance to a vine with its clusters (ἄμπελος). I cannot refer it to any known class of animals.

13. LUNULA OBSCURA. This new genus is characterized by lunate impressions along the sides of an axis; and perhaps they are made by a Myriapod. But the specimens are rather indistinct.

14. BISULCUS UNDULATUS.

15. TRISULCUS LAQUEATUS. The Ichnology has a *Unisulcus.* The etymology of the above two new genera will show their essential character. They were doubtless Annelids.

Insect Tracks.

Though the Ichnology does not undertake to distinguish between the tracks of Insects, Crustaceans, and Myriapods, yet it describes six species that had six feet with single linear extremities, and we can hardly doubt that these were insects. It also describes in the same group six other analogous species, some of which had apparently only two and others four feet. Yet on one or two specimens there appeared, occasionally at least, tracks of at least a second set of feet; and the suggestion was made, that probably they had the six feet of insects, but only two or four of them usually left an impression. Several specimens recently obtained completely confirm this view. It is exceedingly probable, then, that at least fourteen species of insect tracks are described in the Ichnology. To these may be added two new ones, which follow, one of which seems to be a new genus.

16. Bifurculapes curvatus. The tines of the fork are so curved here as to be distinctive of a species.

17. Harpepus capillaris. The principal feet are beautifully curved, and the mud at the larger end of the track is crowded into a bunch, that may be regarded as a short handle to the sickle (ἅρπη, a sickle). The curve of the sickle is as fine as a delicate hair: hence the specific name.

The other fourteen species are the following (see Ichnology): —

Acanthichnus cursorius.
A. saltatorius.
A. tardigradus.
Conopsoides larvalis.
Grammepus erismatus.
Lithographus hieroglyphicus.
L. cruscularis.
Hexapodichnus magnus.
H. horrens.
Bifurculapes laqueatus.
B. tuberculatus.
B. scolopendroides.
B. elachistotatus.
Copeza triremis.

If these conclusions are correct, they show the presence, during the Connecticut River sandstone period, of numerous insects, and thus the probability is increased that this rock is Jurassic rather than Triassic; for of the species of fossil insects described by Bronn, only nine occur below the oölite, and one hundred and nineteen in that formation.

Peculiar and Undetermined Specimens.

18. Scalichnus incertus.

These impressions are very distinct; and if we look only at the ladder-like rows, of which the specimen shown contained several, we should hardly doubt that they are tracks; but the whole slab is covered with analogous markings, and there are some rows of them that seem as if of vegetable origin. Though a name is for convenience attached to these specimens, yet it is extremely difficult to make up one's mind as to their character.

19. PERHAPS CRUSTACEAN TRACKS.

Some large and remarkable slabs were described under this head. On these slabs, the largest three and a half by four and a half feet, may be noticed the following: —

1. Several perfectly straight grooves or furrows, perfectly parallel, sometimes not half an inch apart, resembling drift furrows.

2. Numerous rows of impressions, not less certainly than thirty-five, running across the slab, nearly parallel to one another and to the grooves, but sometimes intersecting at a small angle, and apparently independent of the grooves.

3. Circular dents, as if made by a blunt stick, but nearly equidistant; sometimes elongated and linear, sometimes boot-shaped, sometimes with a trifid arrangement in equidistant steps.

4. Three deeper and distinct furrows, parallel to the others, evidently tail-traces, from which small ripple-marks proceed like the vane of a feather.

An excellent photograph of the largest slab was exhibited; also outlines, several inches long, of the ten or twelve varieties of impressions of the natural size. By the aid derived from a recent paper in the Canadian Naturalist, by Dr. Dawson, " On the Footprints of Limulus, as compared with the Prototichnites of the Potsdam Sandstone," the suggestion was made that these impressions might have been the work of an analogous Crustacean.

Supposed Mistake as to the number of Phalanges in the thick-toed Animals that made the Footmarks in the Connecticut Valley.

The opinion seems to have been unanimous, with all who have examined the footmarks of the Connecticut Valley, that the number of phalanges denoted by the impressions in the thick-toed bipeds corresponds to those of most tridactyle birds, viz. (omitting the ungual phalanx, which would not show an impression distinct from that made by the penultimate phalanx) two in the inner toe, three in the middle, and four in the outer toe. And this is certainly the conclusion to which the best specimens would naturally lead. But recent examinations have led to the conviction that *one phalanx too many has been assigned to the outer toe.* If any one will look at the outline sketches of the fourteen species of thick-toed birds, as they are called, given in the Ichnology, — or, better still, if he will look at the specimens in the cabinet, from which these were copied, — he will see that the hindmost phalanx of the outer toe lies entirely farther back, or nearly so, than the first phalanx of either of the other toes, so far as the author had been able to ascertain since this subject had arrested his attention. This is not the case in living animals; but in birds especially, the first phalanx of the outer toe is abreast of that in the inner toe, though in the middle toe it is usually a little in advance of the others. Hence, what has been regarded as the imprint of the first phalanx of the outer toe was probably made by a heel-bone; and indeed in some cases this impression differs somewhat from the others. Hence the true number of phalanges in these fossil animals was three in the inner toe, and four in both the other toes. The author did not feel entirely satisfied that this conclusion would stand; but he had become more and more convinced of its truth, the more he examined the subject. Want of access to large collections of living animals and ill health had embarrassed his investigations.

Do the Protuberances on the under side of the toes correspond to the number of Phalanges, or to that of the articulations, or to neither?

These questions sprung up during this investigation, and have led to some examination. Plaster moulds of the feet of a few birds have been taken, which were exhibited, whose characters are as follows.

The protuberances on the foot of the turkey, both wild and domestic, correspond neither with the phalanges nor the articulations. They are more numerous than either, and very unequal as to size and depth. As many as six or seven can be counted. Those of the domestic hen are very similar.

In the *Botanus lentiginosus* they correspond to the articulations, — certainly so on the dried specimen from which the mould was taken.

The wings on the toes of the Coot expand along the phalanges, and contract at the joints. The expansions in the Crow's foot correspond to the articulations, as is learnt from some impressions on clay from the banks of Connecticut River.

A good mould of the feet of the South American Ostrich (*Rhea Americana*) shows rather indistinctly the normal number of phalanges in the middle toe, but gives no idea of the number in the other toes. This mould was taken by Professor Jeffries Wyman.

These results show the need of further investigations in this direction. They awaken a deeper interest in the remarkable uniformity of the phalangeal impressions of the fossil footmarks, apparently so much more perfect than in living animals.

Were any of the Animals that made the Fossil Footmarks Birds?

The facts above stated as to the number of phalanges, if admitted, of which some doubt may still remain, very much weaken the strongest argument for the ornithic character of the thick-toed bipeds; perhaps they are absolutely fatal to such an opinion; yet in all other respects the tracks correspond with those of birds. They were undoubtedly bipeds, and the long stride taken by some of them corresponds with that of wading birds, but of no other known animals. Whether anatomists would admit that the earliest birds might have been so unlike the present species as to a slight difference in the number of phalanges, must be left for them to decide.

Professor Hitchcock referred to the *Anomœpus* as furnishing another argument against the ornithic character, — especially to a remarkable specimen recently obtained for the Amherst Cabinet. It is eleven feet long, and of its forty-nine tracks, forty-five belong to *Anomœpus*, and sixteen of them are so perfect as to show the papillæ of the toes more or less. A drawing of the slab of the natural size was exhibited, showing the position and form, the phalanges and claws, and the papillæ of the whole. Four rows of the tracks were manifest, the longest containing seventeen tracks, and three of these rows would be pronounced by a good judge of tracks to be those of thick-toed birds; especially as the phalangeal impressions, — certainly on the inner and middle toes, and probably also on the outer one, — correspond with those of birds; that is, as we have been accustomed to regard them. For here, too, the first phalanx of the outer toe is thrown back beyond that of the other toes. On looking, however, at the fourth row, which for the first five steps exactly resembles the others, we find at the fifth step two tracks nearly abreast, with long stout heels running back several inches, and a little in advance two small five-toed impressions; proving beyond all question that the animal was a quadruped with unequal feet and long heels to its hind feet; as is still further proved by the trace of a tail. The animal seems to have rested for a moment upon all its feet; and then it rose and went forward again upon the toes of its hind feet; in other words, it was *digitigrade;* and Professor Hitchcock suggested that several of these ancient animals must have used only the toes of their hind feet in walking, and rarely brought their fore feet to the ground.

We must not hastily conclude from these facts that all the tracks of apparently biped animals in the valley are really those of quadrupeds, which proposition Professor Hitchcock attempted to prove in a paper read before the American Association for the Advancement of Science, at their Newport meeting, and published in their Proceedings. Moreover, he had attempted to show in his Ichnology, that the facts as to the number of phalanges in the *Anomœpus* might be explained without destroying the evidence of an ornithic origin in the fourteen thick-toed bipeds: for other slabs in the cabinet had taught the same facts, though less distinctly than the specimen above described. The facts, however, do show us that the quadrupeds of sandstone days had strong ornithic characters, and they justify the conclusion, that, if none of the animals that made the tracks were veritable birds, they approached very near them in character. Every department of palæontology teaches that many of the ancient animals possessed intermediate characters between the less perfect races that preceded and the more perfect ones that followed, so that we should not think it strange if Ichnology teaches the same, as it does most decidedly; and it may be that, so nearly balanced sometimes are the characters between birds and reptiles, that from tracks alone we may never be able certainly to determine to which class the animals belonged.

The recent discovery in the lithographic quarries at Solenhofen, in Bavaria, of the *Gryphosaurus,* is a striking illustration of this subject. For, according to the discoverer, it was *a feathered fossil reptile,* feathered on the fore legs, and with a radiate fan at the extremity of the tail. Its osteology, also, in some important respects, corresponds to that of birds. Indeed, it was stated by a member of the Academy, that Professor Owen still maintains that this animal was a bird, in opposition to the German anatomists, Wagner and Meyer. But if such eminent authorities differ, when even the skeleton is before them, much more may we hesitate when we have only tracks.

It may be, however, that light may come from Ichnology, which even the fossil skeleton would not teach. Hence the importance of large collections of the footmarks. Professor Hitchcock stated that he had counted the individual tracks in the Amherst Cabinet, and found them to exceed 12,000, nearly 4,000 of which are the tracks of insects. Within a few days, through the liberal donations of a few friends of science, the entire collection of Roswell Field, made at Turner's Falls, has been added, which will increase the collection by several thousand tracks. May they furnish new light to future explorers!

[POSTSCRIPT, *January* 15, 1863. Among the specimens just added to the cabinet, as mentioned above, are some very perfect ones, showing the phalangeal impressions with great distinctness. And one of them, probably a new species of *Anomœpus*, has in the outer toe, besides the hindmost impression, which I now regard as made by a heel-bone, *four other perfectly distinct impressions in at least two tracks.* Here, then, we have the normal number for birds, after setting aside the hindmost. Again, on another quite perfect specimen of a *Grallator*, I find the same facts, — not so distinctly marked, indeed, as in the first case, still obvious enough to a practised eye; and now that attention has been directed to this point, I am anxious to re-examine all my specimens of the fourteen thick-toed bipeds, to see whether they may not all have had the same number of protuberances. I incline to the opinion that it may so turn out; and if so, that we may still confidently maintain that these species were birds. — *March* 20. It so turns out.]

Dr. B. A. Gould directed the attention of the Academy to an echo, of remarkable excellence, in the chimney of the Roxbury Chemical Works.

The buildings have been recently taken down, with the exception of this tall chimney, which must be nearly two hundred feet high, and into which entrance is easy by means of large, door-like flues. Sounds made within the structure are repeated with great distinctness many times, — and repeated trials showed the possibility of obtaining at least ten clearly audible repetitions, for sounds of moderate strength and low pitch, such as that made by stamping with the foot upon the frozen ground. The nearest estimate which Mr. Gould could make with the aid of a common watch, gave $3^s.4$ or $3^s.5$ as the interval between the primitive sound and the tenth echo, — corresponding to a series of reflections from the open end of a pipe about one hundred and ninety feet high, at the temperature of freezing.

The interval before the first echo was sufficient to permit the full utterance of some five-syllabled words, such as "quadrupedante," "anemometer," etc., — which would indicate as much as thirty-five hundredths of a second, at the least possible estimate.

He had not succeeded in learning the actual height of the chimney, but had taken measures to do so, as he hoped by means of a careful determination of the fundamental tone to succeed in setting the whole column of air in vibration.

Articulate sounds of all kinds appeared to be reproduced by the echo without any loss of their original distinctness, except the sibilants. Mr. Gould had found all the other consonants, and many of their combinations, such as *pl*, *cl*, *tr*, *gn*, *kn*, *lt*, as also the aspirate, to be echoed with as perfect enunciation as the original sound. But a hiss, or the letter *s*, was repeated as a very sharp aspiration. The echo of *z* was a softened aspiration, and even *f* and *th* could not be obtained with distinctness. These (including of course *x*) were the only exceptions to completeness of articulation in the echoes. A prolonged musical note filled the cavity with resonance until it was almost unendurable, and it was easy by sounding three harmonic notes, such as C, E, and G, to obtain the effect of a chord in full perfection.

Mr. Safford made the following communication: —

In the sixth volume of his Astronomical Journal, Dr. B. A. Gould has given a detailed investigation of the places of 48 stars within 25° of the North Pole; and has since published the results of a more complete investigation of the places of 40 of these same stars, together with those of 132 stars nearer the equator. The prefatory letters of the pamphlet in which these latter results are contained (without any details of the investigation), bear the dates Sept. 10th, 1862, and Sept. 13th, 1862; though the work seems not to have been published till some months later.

At the meeting of the Academy on Sept. 9th, I presented the results of a somewhat similar investigation upon the positions of 25 stars within 10° of the North Pole; of which 4 were common to my own catalogue and that of Dr. Gould; and also upon the positions of an extensive list of time stars, of which 49 were common to the two. My Memoir (now in the hands of the Publishing Committee of the Academy) contained also the positions of 47 stars extracted from the materials of Wolfers's *Tabulæ Reductionum.*

The four polar stars differ thus in the two catalogues (G. denoting Dr. Gould's results, S. my own, in both cases reduced to the ecliptic of 1855) for the time 1855 + t.

	G. — S.			
	$\Delta\alpha$		$\Delta\delta$	
51 Cephei H.	$-0^s.66$	$-0^s.0752\,t$	$-0''.40$	$+0''.026\,t$
1 Draconis H.	-0.13	$-0.0127\,t$	$+0.10$	$+0.005\,t$
ε Ursæ Minoris	-0.09	$+0.0039\,t$	$+0.06$	
λ Ursæ Minoris B.	-0.14	$+0.0023\,t$	-0.11	

Much the largest discrepancy occurs in the case of 51 Cephei H.; for which Dr. Gould has omitted the best early authority, — Struve, of 1815, — and employed unreliable catalogues (Lalande, Piazzi, Groombridge, for A.R.), with uncertain corrections for the proper motions. His formula differs, therefore, from observation, by more than 2^s in 1815, and by varying amounts, but with the same sign, from every published year's work (but one) of an observatory, since 1854, the date of the last observations employed. The single exception is the Washington Observations of 1861, where the erroneous place of this same star was used (by a peculiar process)* in determining itself over again. The time stars of the two lists agree better; the following table gives the differences for 1855. Stars which in my memoir are quoted from the excellent catalogue of Wolfers have numbers corresponding to them in the *second* column; the results of comparison of my own catalogue are contained in the *third* column; the first being occupied by the star's name. The initials W., G., S., denote the right ascensions of the three catalogues for 1855.

The mean of the 30 Nos. W. — G. is $+0^s.033$; mean diff. from this mean $\pm 0^s.0205$.
" " 49 " S. — G. $+0^s.026$; " " " $\pm 0^s.0213$.

The largest discrepancy is in the case of β Corvi. There is some doubt about Bradley's *two* observations of this star; one or both of them are 1^s wrong.

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* These Washington observations of 51 Cephei are almost exclusively such that the instrumental corrections depend on this star and δ Ursæ Minoris. Let e be the error of the assumed A.R. of 51 Cephei, and e' that of δ Ursæ. The error hence resulting of the deviation (n) of the transit instrument at the pole will be $\frac{e - e'}{\tan\delta + \tan\delta'}$ or, for these stars, $\frac{e - e'}{20.8 + 16.9} = \frac{e - e'}{37.7}$; and the resulting error of the position of 51 Cephei will be $20.8\,\frac{e - e'}{37.7} = 0.55\,e - 0.55\,e'$; that is, the so-called observed position (even deduced from 100 or 1,000 observations) will be erroneous by *more than one half* the algebraic difference of the errors of the two catalogue positions. The process is one not approved by European astronomers.

	W. — G.	S. — G.		W. — G.	S. — G.
α Andromedæ	^{s}+0.010		β Corvi		^{s}+0.095
γ Pegasi	+0.067		12 Canum Ven.		+0.028
β Ceti		^{s}+0.038	θ Virginis		—0.006
ε Piscium		—0.022	α Virginis	^{s}+0.007	
θ Ceti		+0.017	ζ Virginis		+0.018
η Piscium		+0.061	η Boötis		+0.025
β Arietis		+0.043	α Boötis	+0.019	
α Arietis	+0.040		ε Boötis		+0.027
γ Ceti		+0.018	α^2 Libræ	+0.013	
α Ceti	+0.011		β Libræ		+0.021
η Tauri		+0.030	α Coronæ	+0.048	
γ Eridani		—0.008	α Serpentis	+0.044	
ε Tauri		+0.052	δ Ophiuchi		+0.027
α Tauri	+0.019		α Scorpii	—0.001	
ι Auriga		+0.026	κ Ophiuchi		+0.043
α Auriga	+0.041		α Herculis	+0.063	
β Orionis	+0.044		α Ophiuchi	+0.041	
β Tauri	+0.027		μ Herculis		+0.039
δ Orionis		+0.030	μ^1 Sagittarii		+0.012
α Leporis		+0.005	α Lyræ	+0.041	
ε Orionis		+0.024	β Lyræ		+0.044
α Orionis	+0.039		ζ Aquilæ		+0.044
μ Geminorum		+0.055	δ Aquilæ		+0.043
γ Geminorum		+0.046	γ Aquilæ	+0.051	
ε Canis Majoris		+0.010	α Aquilæ	+0.071	
δ Geminorum		+0.011	β Aquilæ	+0.060	
β Geminorum	+0.016		α^2 Capricorni	+0.054	
ι Navis		+0.008	α Cygni	+0.020	
ε Hydræ		+0.001	ζ Cygni		+0.046
α Hydræ	+0.015		β Aquarii		+0.025
ε Leonis		+0.021	ε Pegasi		+0.012
α Leonis	—0.007		α Aquarii	+0.050	
γ Leonis, pr.		+0.049	θ Aquarii		0.000
ρ Leonis		+0.008	η Aquarii		+0.010
l Leonis		+0.080	ζ Pegasi		+0.030
δ Leonis		+0.029	α Piscis Aust.	+0.015	
δ Crateris		+0.027	α Pegasi	+0.049	
ε Leonis		+0.002	ι Piscium		+0.006
β Leonis	+0.019		ω Piscium		+0.012
η Virginis		+0.015			

Five hundred and sixteenth Meeting.

January 13, 1863. — MONTHLY MEETING.

THE PRESIDENT in the chair.

The Corresponding Secretary read a letter from Dr. C. M. Warren, in acknowledgment of his election as a Fellow. Also various letters relative to the exchanges of the Academy.